Cambridge University Press
978-1-108-42826-2 — Introduction to Optics
Frank L. Pedrotti , Leno M. Pedrotti , Leno S. Pedrotti
Frontmatter
More Information

INTRODUCTION TO OPTICS

THIRD EDITION

Introduction to Optics is now available in a re-issued edition from Cambridge University Press. Designed to offer a comprehensive and engaging introduction to intermediate and upper-level undergraduate physics and engineering students, this text also allows instructors to select specialized content to suit individual curricular needs and goals.

Specific features of the text, in terms of coverage beyond traditional areas, include extensive use of matrices in dealing with ray tracing, polarization, and multiple thin-film interference; three chapters devoted to lasers; a separate chapter on the optics of the eye; and individual chapters on holography, coherence, fiber optics, interferometry, Fourier optics, nonlinear optics, and Fresnel equations.

FRANK L. PEDROTTI, S. J. (1932–2010) was a member of the Society of Jesus and served on the faculty at a number of institutions, including Marquette University, from 1977 to 1994. He received a Ph.D. in Physics from the University of Cincinnati in 1962. His research areas included solid state physics and laser optics and he taught and developed courses across the undergraduate curriculum. His course notes served as the basis for the first edition of the text *Introduction to Optics*, which he co-authored with his brother, Leno S. Pedrotti.

LENO M. PEDROTTI is a professor of Physics at the University of Dayton, where he joined the faculty in 1987, after completing his Ph.D. at the University of New Mexico in 1986. He has published papers on a variety of topics in theoretical quantum optics, including the quantum theory of the laser, microcavity lasers, nonclassical states of light, and atom/field/cavity interactions. He has taught courses that span the undergraduate physics curriculum, as well as selected graduate electro-optics courses.

LENO S. PEDROTTI (1927–2008) was a professor of Physics at the Air Force Institute of Technology (AFIT) and Chief Scientist and Senior Vice President at the Center for Occupational Research & Development (CORD). He earned a Ph.D. in Physics from the University of Cincinnati in 1961. He joined AFIT in 1951, where he served as chair of the Physics Department from 1964 to 1982. At CORD, he spearheaded the development of technical education materials for high-school and college students. His research areas included solid state physics and laser optics. He was a fellow of the Optical Society of America.

To our families and friends for their timely support during the preparation of this textbook.

INTRODUCTION TO OPTICS

THIRD EDITION

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Deceased

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Brief Contents

Contents

Cambridge University Press
978-1-108-42826-2 — Introduction to Optics
Frank L. Pedrotti , Leno M. Pedrotti , Leno S. Pedrotti
Frontmatter
More Information

Cambridge University Press
978-1-108-42826-2 — Introduction to Optics
Frank L. Pedrotti , Leno M. Pedrotti , Leno S. Pedrotti
Frontmatter
More Information

Part II

Physical Constants

Speed of light	$c = 2.998 \times 10^{8}$ m/s
Electron charge	$e = 1.602 \times 10^{-19}$ C
Electron rest-mass	$m = 9.109 \times 10^{-31}$ kg
Planck constant	$h = 6.626 \times 10^{-34}$ J-s
Boltzmann constant	$k = 1.3805 \times 10^{-23}$ J/K
Permittivity of vacuum	$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2/N-m^2
Permeability of vacuum	$\mu_0 = 4\pi \times 10^{-7}$ T-m/A

Preface

INTRODUCTION

The field of optics impacts an ever-expanding range of applications in physics, engineering, and technology. The parallel emergence of lasers, fiber optics, nonlinear devices, and a variety of semiconductor sources and detectors in the 1960s initiated a continuing period of rapid development in applied and theoretical optics. The need for a variety of updated optics texts with different approaches and emphases is apparent, both for students of optics and for practitioners who need an occasional review of the basics.

With *Introduction to Optics* we propose to teach introductory modern optics at an intermediate level. In order to use this text, students should have a preparatory background that includes a calculus-based introductory physics sequence and at least two semesters of calculus. The material in this text encompasses the traditional areas of classical optics and many topics in modern optics. The organization of the material in this text is intended to facilitate its use in a variety of one-semester courses, with different emphases. In addition, the text includes more than enough material to be used in a full-year optics course for physics or engineering students at the sophomore, junior, or senior undergraduate level.

Specific features of the text, in terms of coverage beyond traditional areas, include extensive use of 2×2 matrices in dealing with ray tracing, polarization, and multiple thin-film interference; three chapters devoted to lasers; a separate chapter on the optics of the eye; and individual chapters on holography, coherence, fiber optics, interferometry, Fourier optics, nonlinear optics, and Fresnel equations. We have organized the text into two parts. Part I includes chapters that form the basis of a typical one-semester optics course designed for sophomore or junior physics majors. Chapters in Part I are designed to be covered in sequence, although subsets of these chapters can be omitted to suit specific curricular needs. Part II contains chapters that are

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Frontmatter
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largely self-contained and, upon completion of a subset of chapters in Part I, can be covered in a variety of sequences. We hope that this organization will allow teachers to select specialized content to suit individual curricular needs. Possible orderings of chapter coverage appropriate for several possible optics courses with different emphases are provided later in this Preface.

IMPROVEMENTS IN THE THIRD EDITION

The Third Edition of this text differs from the Second Edition in that several topics have been added or expanded and the order of presentation of the material has been changed to provide teachers with greater freedom to tailor the text to meet specific curricular requirements. New features of the Third Edition include the following:

- The treatment of wave equations (Chapter 4) has been expanded with the addition of qualitative descriptions of cylindrical and Gaussian beams and a brief introduction to light polarization.
- The coverage of optical interferometry (Chapter 8) has been expanded by providing a more detailed description of the operation and applications of the Fabry-Perot interferometer and by adding a description of gravitational wave detectors.
- New descriptions of other modern optics applications appear throughout the text. For example, we have added a section on wavelength-division-multiplexing in fiber communication systems in Chapter 10 and we have added sections on liquid-crystal displays and plasma displays in Chapter 17.
- A new chapter (Chapter 26, "Laser Operation") provides both a *quantitative*, rate-equation treatment of laser operation and a qualitative introduction to the semiconductor laser. The four chapters—Chapter 6, "Properties of Lasers," Chapter 26, "Laser Operation," Chapter 27, "Characteristics of Laser Beams," and Chapter 28, "Selected Modern Applications,"—taken together constitute a rather comprehensive introduction to laser optics for undergraduates.
- Based on extensive reviewer feedback we have carefully revised each chapter, sharpening and clarifying discussions and mathematical developments throughout.
- Chapter 28, an expansion and revision of the Second Edition chapter "Laser Applications," includes new sections describing ultrashort pulse production, laser cooling and trapping, optical parametric oscillators, and near-field microscopy.
- More than 100 problems have been added.
- For Instructors, we once again offer an Instructor's Solutions Manual (0-13-173918-2) containing fully worked-out solutions to all end-of-chapter problems. Instructors can also visit the *Introduction to Optics, 3rd Edition* information page on Prentice Hall's online catalog (www.prenhall.com <www.prenhall.com>) to download additional instructor resources, including electronic versions of the figures from *Introduction to Optics, 3rd Edition*.

Nearly all of the material from the Second Edition remains in the Third Edition. We have sharpened and clarified discussions and mathematical discussions throughout.

TEXT ORGANIZATION

The text is divided into two parts. The individual chapters in Part II primarily rely only on material covered in Part I and so can be covered in a variety of different sequences. As an indication of the flexibility of the text, we offer four possible one-semester course organizations.

Traditional "Balanced" Optics Course

Prerequisites: Two or three semesters of introductory physics and two semesters of calculus

Chapter 1 Nature of Light
Chapter 2 Geometrical Optics
Chapter 3 Optical Instrumentation
Chapter 4 Wave Equations
Chapter 5 Superposition of Waves
Chapter 6 Properties of Lasers
Chapter 7 Interference of Light
Chapter 8 Optical Interferometry
Chapter 9 Coherence
Chapter 10 Fiber Optics
Chapter 11 Fraunhofer Diffraction
Chapter 13 Fresnel Diffraction
Chapter 15 Production of Polarized Light

Traditional Course: Geometrical Optics Emphasis

Prerequisites: Two or three semesters of introductory physics and two semesters of calculus

Chapter 1 Nature of Light
Chapter 2 Geometrical Optics
Chapter 3 Optical Instrumentation
Chapter 18 Matrix Methods in Paraxial Optics
Chapter 19 Optics of the Eye
Chapter 20 Aberration Theory
Chapter 4 Wave Equations
Chapter 5 Superposition of Waves
Chapter 6 Properties of Lasers
Chapter 7 Interference of Light
Chapter 8 Optical Interferometry
Chapter 10 Fiber Optics

Physical Optics

Prerequisites: Two or three semesters of introductory physics, two semesters of calculus, and one semester of intermediate electromagnetics

Chapter 1 Nature of Light
Chapter 4 Wave Equations
Chapter 5 Superposition of Waves
Chapter 6 Properties of Lasers
Chapter 7 Interference of Light
Chapter 8 Optical Interferometry
Chapter 9 Coherence
Chapter 11 Fraunhofer Diffraction
Chapter 12 The Diffraction Grating
Chapter 13 Fresnel Diffraction
Chapter 14 Matrix Treatment of Polarization
Chapter 15 Production of Polarized Light
Chapter 16 Holography
Chapter 21 Fourier Optics

Laser Optics

Prerequisites: Two or three semesters of introductory physics, two semesters of calculus, and one semester of intermediate electromagnetics

Chapter 4 Wave Equations
Chapter 5 Superposition of Waves
Chapter 6 Properties of Lasers
Chapter 26 Laser Operation
Chapter 7 Interference of Light
Chapter 8 Optical Interferometry
Chapter 9 Coherence
Chapter 10 Fiber Optics
Chapter 11 Fraunhofer Diffraction
Chapter 14 Matrix Treatment of Polarization
Chapter 15 Production of Polarized Light
Chapter 18 Matrix Methods in Paraxial Optics
Chapter 27 Characteristics of Laser Beams
Chapter 28 Selected Modern Applications

Other chapter sequences are, of course, possible. For example, for advanced undergraduates with two semesters of electromagnetic theory, the Laser Optics course could be altered by replacing Chapters 4, 5, and 7 with Chapters 16 ("Holography"), 22 ("Theory of Multilayer Films"), and 24 ("Nonlinear Optics and the Modulation of Light"). A variety of two-semester, two-quarter, or three-quarter sequences are also possible.

ACKNOWLEDGMENTS

We wish to thank the many teachers who have inspired us with an interest in optics and teaching, and the many students who have motivated us to teach with clarity and efficiency.

First and Second Edition

For their very helpful reading of portions of the manuscript for the First Edition, we are indebted to Hugo Weichel, James Tucci, Hajime Sakai, Arthur H. Guenther, and Thomas B. Greenslade. For their suggestions leading to the Second Edition we wish to thank the team of reviewers selected by Prentice Hall: Joel Blatt, Florida Institute of Technology; James Boger, Oregon Institute of Technology; Harry Daw, New Mexico State University; Edward Eyler, University of Delaware; and Daniel Wilkins, University of Nebraska. For his review and suggestions in the chapter on the eye, we are also pleased to acknowledge and thank Dr. Michael Pedrotti, O.D. We also wish to thank Judy Lawson, CORD, for her sketch of Einstein that graces page 1.

Third Edition

Many of the changes made in the Third Edition of the book grew in part from the thoughtful suggestions made by the reviewers: Ralph Alexander, University of Missouri at Rolla; Ramendra Bahuguna, San Jose State University; Robert M. Bunch, Rose-Hulman Institute of Technology; Henry J. Leckenby, Texas A&M, Kingsville; Peter G. LoPresti, University of Tulsa; Sergey Mirov, University of Alabama, Birmingham; B. Paul Padley, Rice University; Jie Shan, Case Western University; John E. Sohl, Weber State University; Rick Trebino, Georgia Tech; and Paul Voytas, Wittenberg University. We are deeply indebted to this group of reviewers for their valuable suggestions. From this group we wish to extend special thanks to John Sohl and Robert Bunch for their careful reading of the entire Third Edition. We would also like to thank Robert Brecha, Bruce Craver, and Peter Powers from the University of Dayton for suggestions and advice leading to some of the new material in the Third Edition and Mark Whitney and Kathy Kral of CORD for artistic and logistical help.

Finally, we express our gratitude to the editorial and production staff of Prentice Hall for their enthusiastic and professional support. In particular, we are indebted to our acquisitions editors, Holly Hodder for the First Edition, Ray Henderson for the Second Edition, and Erik Fahlgren for the Third Edition, and to our production editors, Kathleen Lafferty for the first two editions and Kevin Bradley and Cindy Miller (of GGS Book Services) for the Third Edition. All efforts were made to ensure accuracy, but responsibility for all errors lie with authors.

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